



# Cboe Volatility Index (VIX®)

## Index Rules & Methodology

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# Index Construction

## Overview

Cboe Exchange, Inc. (Cboe), in its capacity as a reporting authority, calculates and disseminates the Cboe Volatility Index® commonly known as the "VIX® Index" (ticker: VIX). The VIX Index is a financial benchmark designed to be an up-to-the-minute market estimate of the expected volatility of the S&P 500® Index, and is calculated by using the midpoint of real-time S&P 500® Index (SPX) option bid/ask quotes. More specifically, the VIX Index is intended to provide an instantaneous measure of how much the market expects the S&P 500 Index will fluctuate in the 30 days from the time of each tick of the VIX Index.

Intraday VIX Index values are based on snapshots of SPX option bid/ask quotes every 15 seconds and are intended to provide an indication of the fair market price of expected volatility at particular points in time. As such, these VIX Index values are often referred to as "indicative" or "spot" values. Cboe currently calculates VIX Index spot values between 2:15 a.m. CT and 8:15 a.m. CT (Cboe GTH session), and between 8:30 a.m. CT and 3:15 p.m. CT (Cboe RTH session).

As described in greater detail below, Cboe applies a filtering algorithm to the calculation of spot VIX Index values in order to identify and suppress VIX Index values that, while reflecting SPX option quotes at a particular point in time, do not reflect the expected volatility of the S&P 500 Index.

Cboe, in its capacity as a reporting authority, also calculates and disseminates "Special Opening Quotations" ("SOQ") of the VIX Index that are used as Final Settlement Values for VIX futures and VIX options. VIX "SOQ" values are calculated only once on the days that VIX futures and VIX options expire and are based on opening trade prices of SPX options with 30 days to expiration.

## The VIX Index Formula

The generalized formula used in the VIX Index calculation<sup>1</sup> is:

$$\sigma^2 = \frac{2}{T} \sum_i \frac{\Delta K_i}{K_i^2} e^{RT} Q(K_i) - \frac{1}{T} \left[ \frac{F}{K_0} - 1 \right]^2$$

### WHERE...

$\sigma$	$\frac{VIX}{100} \Rightarrow VIX = \sigma \times 100$
T	Time to expiration
F	Forward index level derived from index option prices
$K_0$	First strike below the forward index level, F
$K_i$	Strike price of $i^{th}$ out-of-the-money option; a call if $K_i > K_0$ and a put if $K_i < K_0$ ; both put and call if $K_i = K_0$ .

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<sup>1</sup> See *More Than You Ever Wanted to Know About Volatility Swaps*, by Kresimir Demeterfi, Emanuel Derman, Michael Kamal and Joseph Zou, Goldman Sachs Quantitative Strategies Research Notes, March 1999, publicly available at: <http://www.emanuelderman.com/writing/entry/more-than-you-ever-wanted-to-know-about-volatility-swaps-the-journal-of-der>.

$\Delta K_i$  Interval between strike prices – half the difference between the strike on either side of  $K_i$ :

$$\Delta K_i = \frac{K_{i+1} - K_{i-1}}{2}$$

(Note:  $\Delta K$  for the lowest strike is the difference between the lowest strike and the next higher strike. Likewise,  $\Delta K$  for the highest strike is the difference between the highest strike and the next lower strike.)

R Risk-free interest rates to expiration

$Q(K_i)$  The average of the bid quote and ask quote for each option with strike  $K_i$ .

## Time to Expiration for Constituent Options

The VIX Index measures the 30-day expected volatility of the S&P 500 Index. The components of the VIX Index are at- and out-of-the-money put and call options with more than 23 days and less than 37 days to a Friday SPX expiration date. These include AM-settled SPX options with “standard” 3<sup>rd</sup> Friday expiration dates and PM-settled “weekly” SPX options that expire every Friday, except the 3<sup>rd</sup> Friday of each month<sup>2</sup>. Once each week, the SPX options used to calculate the VIX Index “roll” to new contract maturities. For example, on the day before VIX futures and VIX options expiration, the VIX Index is generally calculated using two SPX option expirations: (1) one expiring 24 days later (i.e., “near-term”) and, (2) one expiring 31 days later (i.e., “next-term”). On the following day, the SPX options that expire in 30 calendar days become the “near-term” options and the SPX options that expire a week later are “rolled” in as the “next-term” options.

The VIX Index calculation measures time-to-expiration in calendar days and divides each day into minutes in order to replicate the precision that is commonly used by professional option and volatility traders. N represents time-to-expiration in minutes and T represents time-to-expiration in years. The time-to-expiration is given by the following expressions:

$$N = M_{\text{Current day}} + M_{\text{Settlement day}} + M_{\text{Other days}}$$

$$T = N / \text{Minutes in a year}$$

### WHERE...

$M_{\text{Current Day}}$  = minutes remaining until midnight of the current day

$M_{\text{Settlement day}}$  = minutes from midnight until 8:30 a.m. for “standard” AM-settled SPX expirations;  
or minutes from midnight until 3:00 p.m. for “weekly” PM-settled SPX expirations

$M_{\text{Other days}}$  = total minutes in the days between current day and expiration day

## Risk-Free Interest Rates

The risk-free interest rates,  $R_1$  and  $R_2$ , are yields based on U.S. Treasury yield curve rates (commonly referred to as “Constant Maturity Treasury” rates), to which a cubic spline is applied to derive yields on the expiration dates

<sup>2</sup> If the expiration date for Friday-expiring S&P 500 Index options is moved due to an exchange holiday, the time to expiration for constituent options will be adjusted accordingly.

of relevant SPX options. As such, the VIX Index value calculation may use different risk-free interest rates for near- and next-term options.

## Selecting the options to be used in the VIX Index calculation

The selected options are out-of-the-money SPX calls and out-of-the-money SPX puts centered around an at-the-money strike price,  $K_0$ .  $K_0$  is defined as the strike price that equals or is immediately below the forward index level,  $F_j$ , for the near- and next-term options:

$$F_j = \text{Strike Price}_j + e^{R_j T_j} \times (\text{Call Price}_j - \text{Put Price}_j)$$

### WHERE...

$F_j$ =	Forward SPX level ( $j=1$ for near-term maturity, $j=2$ for next-term maturity)
Strike Price <sub><math>j</math></sub> =	The strike price at which the absolute difference between the Call Price <sub><math>j</math></sub> and Put Price <sub><math>j</math></sub> is smallest.
$R_j$ =	Risk-Free Interest Rate for $j^{\text{th}}$ maturity
$T_j$ =	Time to expiration for $j^{\text{th}}$ maturity
Call Price <sub><math>j</math></sub> =	Average of Call bid quote and Call ask quote for $j^{\text{th}}$ maturity
Put Price <sub><math>j</math></sub> =	Average of Put bid quote and Put ask quote for $j^{\text{th}}$ maturity

The near-term and next-term SPX options used in each VIX Index value calculation are selected using the following steps:

### **Out-of-the-money put options with strike prices < $K_0$**

Start with the put strike immediately lower than  $K_0$  and move to successively lower strike prices. Exclude any put option that has a bid price equal to zero (i.e., no bid). As shown below, once two puts with consecutive strike prices are found to have zero bid prices, no puts with lower strikes are considered for inclusion. (Note that the 2350 and 2355 put options are not included despite having non-zero bid prices.)

Put Strike	Bid	Ask	Include?
2345	0	0.15	<i>Not considered following two zero bids</i>
2350	<b>0.05</b>	<b>0.15</b>	
2355	<b>0.05</b>	<b>0.35</b>	
2360	0	0.35	No
2365	0	0.35	No
2370	0.05	0.35	Yes
2375	0.1	0.15	Yes
2380	0.1	0.2	Yes
.	.	.	.

**Out-of-the-money call options with strike prices > K<sub>0</sub>**

Start with the call strike immediately higher than K<sub>0</sub> and move to successively higher strike prices, excluding call options that have a bid price of zero. As with the puts, once two consecutive call options are found to have zero bid prices, no calls with higher strikes are considered. (Note that the 3225 call option is not included despite having a non-zero bid price.)

Call Strike	Bid	Ask	Include?
.	.	.	.
3095	0.05	0.35	Yes
3100	0.05	0.15	Yes
3120	0	0.15	No
3125	0.05	0.15	Yes
3150	0	0.10	No
3175	0	0.05	No
3200	0	0.05	Not considered following two zero bids
<b>3225</b>	<b>0.05</b>	<b>0.10</b>	
3250	0	0.05	
.	.	.	

**At-the-money call and put options with strike price = K<sub>0</sub>**

Select both the put and call with strike price K<sub>0</sub>. Notice that two options are selected at K<sub>0</sub>, while a single option, either a put or a call, is used for every other strike price.

**Determining prices for the selected options**

The price of each put option with a strike price < K<sub>0</sub> and each call option with a strike price > K<sub>0</sub> is the average of that option's bid quote and ask quote. For the purpose of the VIX Index calculation, the bid/ask quotes of the put and call with strike price equal to K<sub>0</sub> are combined into a single price.

$$Q(K_{i,j} < K_{0,j}) = (\text{Put Bid}_{i,j} + \text{Put Ask}_{i,j}) / 2$$

$$Q(K_{i,j} > K_{0,j}) = (\text{Call Bid}_{i,j} + \text{Call Ask}_{i,j}) / 2$$

$$Q(K_{i,j} = K_{0,j}) = (\text{Put Bid}_{i,j} + \text{Put Ask}_{i,j} + \text{Call Bid}_{i,j} + \text{Call Ask}_{i,j}) / 4$$

## Determining the contribution of both near-term and next-term options

Applying the generalized VIX Index formula, set forth earlier, to the near-term and next-term options with time-to-expiration of  $T_1$  and  $T_2$ , respectively, yields:

$$\sigma^2_{T_1} = \frac{2}{T_1} \sum_i \frac{\Delta K_i}{K_i^2} e^{R_i T_1} Q(K_i) - \frac{1}{T_1} \left[ \frac{F_1}{K_0} - 1 \right]^2$$

$$\sigma^2_{T_2} = \frac{2}{T_2} \sum_i \frac{\Delta K_i}{K_i^2} e^{R_i T_2} Q(K_i) - \frac{1}{T_2} \left[ \frac{F_2}{K_0} - 1 \right]^2$$

Generally,  $K_i$  is half the difference between the strike prices on either side of  $K_i$ . For example, the  $K$  for a SPX put option with a strike price of 2400 that is bracketed by a SPX 2375 put and a SPX 2410 put is 17.5:  $K_{2400 \text{ Put}} = (2410 - 2375)/2$ .

The  $K$  for the options with the highest and lowest strike prices with the same maturity is the difference between that option's strike price and the strike price of the adjacent option. For example, if the lowest strike price was 2370 and the adjacent strike price was 2375, then  $K_{2370 \text{ Put}}$  would be 5 (i.e.,  $2375 - 2370$ ).

Combining  $\tilde{\sigma}^2_{T_1}$  and  $\tilde{\sigma}^2_{T_2}$  into a 30-day weighted average and calculating the VIX Index value:

$$\text{VIX Index} = 100 \times \sqrt{\left\{ T_1 \sigma^2_{T_1} \left[ \frac{N_{T_2} - N_{30}}{N_{T_2} - N_{T_1}} \right] + T_2 \sigma^2_{T_2} \left[ \frac{N_{30} - N_{T_1}}{N_{T_2} - N_{T_1}} \right] \right\} \times \frac{N_{365}}{N_{30}}}$$

$N_{T_1}$  = number of minutes to expiration of the near-term options

$N_{T_2}$  = number of minutes to expiration of the next-term options

$N_{30}$  = number of minutes in 30 days ( $30 \times 1,440 = 43,200$ )

$N_{365}$  = number of minutes in a 365-day year ( $365 \times 1,440 = 525,600$ )

## VIX Index Filtering Algorithm

As described above, "spot" VIX Index values are based on the average of SPX option bid/ask quotes ("mid-quote" prices), and only options that have a non-zero bid price are included. The bid-ask spread is generally accepted as a current indication of market price, and the average of the bid and ask quotes can be thought of as an indication of "fair" value. Spot VIX Index values are calculated using mid-quote option prices that are assumed to reflect these option fair values.

From time to time, option price quotations widen due to changing market conditions, technology failures or other reasons. When this occurs, options that were previously included in a VIX Index value calculation might be excluded due to them now having a zero-bid price. In other instances, the mid-quote prices of one or more SPX options might materially change. This can result in a VIX Index value that, while accurately reflecting SPX option quotes at the time, does not reflect the expected volatility of the S&P 500 Index.

The VIX Index Filtering Algorithm operates as follows:

1. The first VIX Index spot value calculated during the Cboe RTH session or the Cboe GTH session is deemed to be the “baseline” VIX Index spot value.
2. Any VIX Index spot value calculated after and within two (2) minutes of the baseline that is higher than the baseline value or lower than the baseline value by .49 volatility points or less becomes the new baseline value.<sup>3</sup>
3. If VIX Index spot values calculated after and within two (2) minutes of a baseline are lower than the baseline by 0.50 volatility points or more, then the baseline VIX Index spot value will be republished as the VIX Index spot value.
4. If the published VIX Index spot values remain the same for a period of two (2) minutes because the calculated values are 0.50 or more volatility points lower than the baseline, the first VIX Index spot value calculated after the two-minute period becomes the new baseline VIX Index spot value.
5. The filtering algorithm does not apply to the first VIX Index spot value calculated during the Cboe RTH session (approximately 8:30 a.m. CT) or the first VIX Index spot value calculated during the Cboe GTH session (approximately 2:15 a.m. CT). All other VIX Index spot values calculated during Cboe RTH and Cboe GTH are subject to the filtering process.

### Calculation of VIX “Special Opening Quotation”

In addition to “spot” VIX Index values, Cboe, in its capacity as a reporting authority, calculates and disseminates a “Special Opening Quotations” (“SOQ”) of the VIX Index that are used to determine the Final Settlement Values for expiring VX futures and VIX options. Cboe calculates VIX SOQ values only on days when VX futures and VIX options expire. On those days, Cboe calculates a single VIX SOQ value.

The selection process for the SPX options used to calculate the SOQ for expiring VIX derivatives is nearly identical to that which is used to calculate “spot” values of the VIX Index itself. Specifically, the VIX Index methodology used to calculate the SOQ initially selects a universe of at- and out-of-the-money SPX put and call options from a single SPX expiration (vs. two SPX expirations typically used to calculate the spot VIX Index). It then excludes SPX series that have a zero bid price. Furthermore, the methodology truncates the SPX series used to calculate the VIX Index after encountering two consecutive series having “zero-bid” prices, even if further out-of-the-money series have “non-zero” bids.

There is a key difference in the methods used to calculate the VIX SOQ and VIX Index spot values. “Spot” values of the VIX Index are calculated using the midpoint of bid/ask quotes of SPX options, while the VIX SOQ is calculated using actual opening trade prices of SPX options with exactly 30 days to expiration. The opening prices of these options are determined through Cboe’s proprietary auction mechanism known as the Hybrid Opening System (“HOSS”).

In the event that there is no opening traded price for an option, the price used in the VIX SOQ calculation is the average of the first bid and offer disseminated by Cboe for that option. If the first bid disseminated by Cboe in a particular SPX option is zero, then the best unexecuted bid immediately after the HOSS auction match, if any, is

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<sup>3</sup> Threshold parameters used in the VIX Index Filtering algorithm are subject to change at any time in response to changing levels of volatility or other market conditions. Cboe will provide notice to market participants for all such parameter changes.



used as the opening bid. If there is no unexecuted bid immediately after the HOSS auction match, then that option is deemed to be “zero-bid” and is excluded.<sup>4</sup>

For more information on VX futures and VIX options, the process used to calculate VIX SOQ, and the difference between VIX SOQ and VIX Index spot values please visit <http://www.cboe.com/products/vix-index-volatility/vix-options-and-futures/vix-index/vix-faqs#6>.

## Related VIX Values

In addition to the VIX Index, Cboe publishes the Cboe VIX Indicative Bid Index (“VWB”), a VIX Index value based on SPX bid quotes, and the Cboe VIX Indicative Ask Index (“VWA”), a VIX Index value based on SPX option ask quotes. These values provide a market estimate of SPX option bid-ask “spreads” expressed in volatility terms. Cboe also publishes volatility information related to the near-term and next-term VIX Index “components”, <sub>1</sub> and <sub>2</sub>, the Cboe Near-Term VIX Index (“VIN”) and Cboe Far-Term VIX Index (“VIF”), respectively, every 15 seconds during each Cboe trading day. Cboe publishes these related VIX values during regular trading hours (“RTH”) only.

## Historical VIX Index Prices

Cboe makes available on its website more than 25 years of historical VIX Index values. Price history for the original Cboe Volatility Index (VXO) based on S&P 100® Index (“OEX® Index”) options is available from 1986 to the present. Historical prices for the VIX Index, VXO Index and Cboe’s other volatility indexes may be found on the Cboe website at <http://www.Cboe.com/micro/IndexSites.aspx> under Cboe Volatility Indexes.

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<sup>4</sup> Unfilled opening only (OPG) orders are used to determine whether an SPX series has a non-zero bid price and eligible for inclusion in the VIX SOQ. Unfilled OPG orders are cancelled after the HOSS auction trade match but prior to the dissemination of the opening bid/ask quote. This means that an SPX series may be included in the VIX SOQ calculation even if the first quote disseminated for that series has a zero bid price.

# Index Governance

## Index Advisory Oversight Body

The Index Advisory Oversight Body (“IAOB”) reviews and approves all material and non-material changes to the Cboe Volatility Index. All members of the Oversight Body are full-time professionals employed by Cboe Global Markets. The IAOB holds regular quarterly meetings, and may meet more frequently, as needed. At each meeting, the IAOB reviews significant market events, material market structure issues and other relevant information since the last IAOB meeting, and determines whether the Cboe Volatility Index continues to meet its stated objective of being a measure of the 30-day implied volatility of the S&P 500 Index.

Cboe Global Markets considers information about changes to its Indices and related matters to be potentially market moving and material. Therefore, all IAOB discussions and materials are confidential.

# Index Policy

## Conflicts of Interest Disclosure

Cboe's **Conflict of Interest Policy** ensures all employees of Cboe are informed of their duty to avoid conflicts, or the appearance of conflicts, that may arise between personal and business interests. This includes any conflicts of interest as they apply to the VIX Index. Should any potential conflicts of interest arise pertaining to the VIX Index, it will be documented in Cboe's **EU Benchmark Control Framework** document.

## Benchmark Complaint Investigation

Persons or entities that own contracts or other financial instruments can make a complaint regarding Benchmarks owned by Cboe and related Cboe Benchmark determination activities. Cboe has an internal procedure in place, **Benchmark Complaint Procedures**, outlining how in its capacity as a Benchmark Administrator, Cboe receives, investigates, and responds to Stakeholder complaints relating to Benchmark determinations. This includes complaints concerning whether a specific Benchmark determination is representative of the underlying interest it seeks to measure, the application of a methodology to a specific Benchmark determination, and other decisions made by Cboe in relation to a Benchmark determination. Cboe's procedures establish (1) a fair review of and timely response to all Complaints, (2) a process for escalating Complaints to Cboe's Index Administration Oversight Body ("IAOB"), (3) and record retention requirements relating to Complaints.

Stakeholders should electronically submit Complaints through Cboe's website at <http://www.cboe.com/aboutcboe/contactcboeadv.aspx>. Cboe may also accept complaints through telephone calls or through other means of communication at its discretion. If the Stakeholder making the Complaint (the "Complainant") provides an e-mail address, Cboe will typically send an acknowledgment within 1 – 3 business days. Questions relating to Benchmark determinations or the electronic submission process may be sent to Cboe's Corporate Planning & Development group at [VIXResearchGroup@cboe.com](mailto:VIXResearchGroup@cboe.com).

All Complaints will be received, investigated, and responded to within a reasonable period of time, and unresolved Complaints will be escalated to the IAOB Chair as it deems appropriate.

## Cessation and Change Procedures

Cboe's internal procedures, **Cessation-Change of VIX Index Methodology**, provides a step-by-step process when Cessation and Changing of the VIX Index Methodology is necessary.

Cboe Research staff monitors market conditions and, from time to time, may determine that a change in the VIX Index methodology and/or index constituents is required to ensure that the VIX Index continues to be an appropriate benchmark for the market it is intended to measure. Research may also determine to cease calculation of the VIX Index due to business or regulatory considerations. In the event Research makes the foregoing determination(s), Research staff will notify the IAOB.<sup>5</sup> The IAOB is responsible for determining if a change is material and if the change is warranted. Once the VIX Index methodology is updated it will need to go through an approval process, including approval from senior management and may be presented to one or more of Cboe's advisory committees as well as the trading community for feedback. Once the VIX Index modification is

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<sup>5</sup> In addition to information and recommendations from Research staff, internal committees may also provide information and/or recommendations to the IAOB regarding changes to the VIX Index methodology and/or index constituents.

made in production, Research will determine if the change is material and if a determination if a rule change and/or notice is required.

### VIX Index Methodology Maintenance Procedures

Cboe's internal procedures, **VIX Index Methodology Maintenance Procedures**, outline the review schedule and publication process when updating the VIX Index Methodology document.

The Research Department Head ("Department Head") reviews all changes to the VIX Index Methodology and is the authority who oversees publishing new versions of the document. The VIX Index Methodology is reviewed at least on an annual basis, and any changes will be determined to be substantive or non-substantive by the Department Head. All substantive changes to the VIX Index Methodology will be presented to the IAOB for review and possible comment. The VIX Index Methodology will be also be sent to the Legal Division for review and possible comment. Once approved by the Department Head, the document will be published on the Cboe website.

### Delisting of SPX Options Contracts

If Cboe ceases to trade SPX options or SPX options prices cease to be available, Cboe may choose to cease publication of the affected index at that time.

### Contact Information

For questions regarding the VIX Index or to request more detailed information on the Control Framework and Oversight Procedures for administering the VIX Index, please contact: [MAS@Cboe.com](mailto:MAS@Cboe.com).

# Index Dissemination

Index levels are available through Cboe Global Markets website [www.Cboe.com/indexes](http://www.Cboe.com/indexes), major quote vendors (see codes below), numerous investment-oriented Web sites, and various print and electronic media.

<b><u>Vendor</u></b>	<b><u>Index Symbol</u></b>
Activ Financial	VIX
Bloomberg	VIX <Index>
CQG	X.VIX
Factset	VIX
IDC	I:VIX
LiveVol	^VIX
Pico	\$VIX
Telekurs - Six Group	VIX
Vela SuperFeed	VIX
Thomson One	VIX-UT
Thomson Eikon	.VIX
Tradestation	\$VIX.X

# Disclaimer

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